GPM Calibration / Validation Radar Requirements Workshop

Briefing: Development of the NASA DPR Sensor (SBIR Project)

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NASA COTR: Steve Bidwell, NASA GSFC

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Project Objectives

- Design and develop a compact, dual-wavelength, solid-state precipitation radar to support GPM Calibration/Validation efforts.

- Provide new measurement capability to further future algorithm development and system design.

- Complement / extend capabilities of well established lower frequency systems.

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Baseline Requirements

Parameter	Requirement
Operating Frequency	Ku & Ka-band near GPM DPR frequencies (100 MHz bandwidth)
Measurements	Reflectivity & Doppler: VV, HH, VH & HV Brightness Temperature: V & H (goal)
Calibration Stability	Reflectivity: Absolute < 1 dB, Precision: < 0.2 dB Doppler: < 1.5 m/s (10 dB SNR)
Profiles	Resolution: 30 m to 150 m (15-m goal) Range Coverage: 150 m to 10 km
Sensitivity (75-m res. @10 km, ave. profile)	Ku-band: 15 dBZ (-5 dBZ goal) Ka-band: 10 dBZ (-10 dBZ goal)

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Baseline Requirements (cont)

Parameter	Requirement
Antenna Beamwidth	< 500 m @ 10 km (3 dB beamwidth)
Matched Beams	3 dB beamwidth within 10 percent Pointing angle within 10 percent
Scanning	Azimuth: 0-360 deg, 10 rpm (36 deg/sec) max Elevation: -10-90 deg elevation, 10 deg/sec max Position: 10 (8) bit encoder or better
Communication	IEEE 802.3, IEEE 802.11 a/b/g (control & data)
Transceiver	Maintain compatibility with HIWRAP system.

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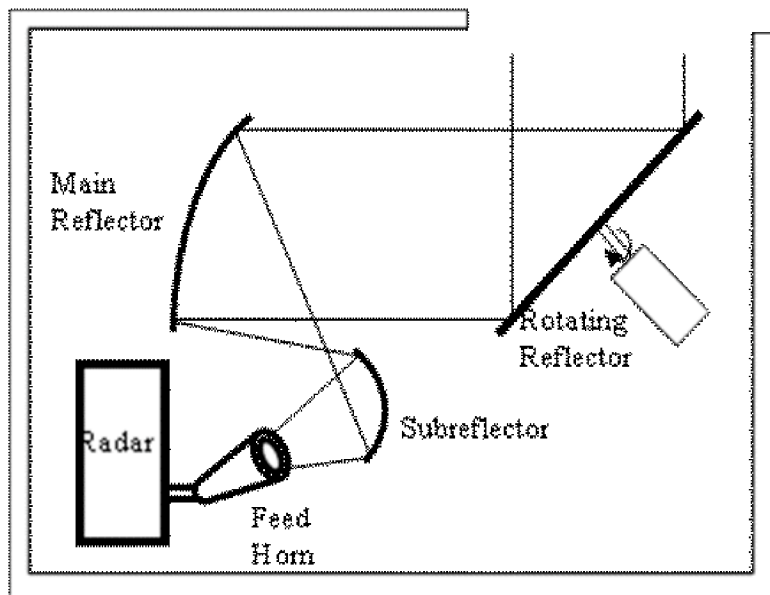
NASA DPR Phase II Effort

- Design & fabricate a dual-wavelength, dual-polarized antenna feed.

- Develop dual-wavelength, scanning antenna system design.

- Design and fabricate dual-wavelength, dual-polarized, active and passive transceiver.

- Develop full system specifications and design for sensor and sensor network.

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DPR Antenna System
Design, Performance & Status

Antenna Concept

Main Reflector

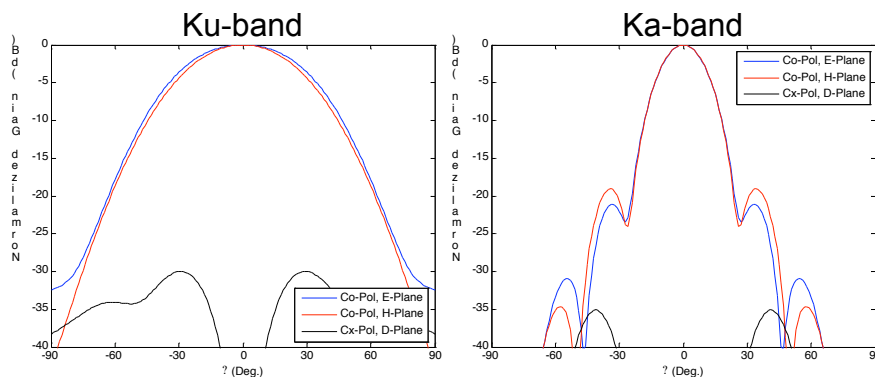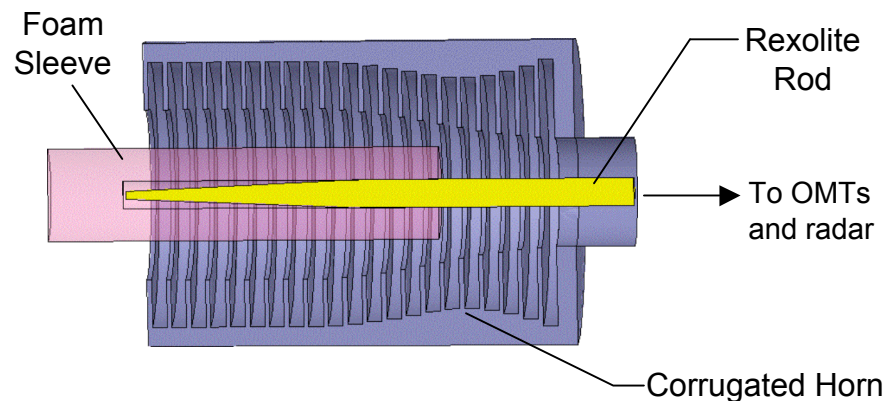Rotating Reflector

Radar

Subreflector

Feed Horn

* Estimated Box Size: 6 ft x 3 ft x 4.5 ft

Main Features

- Dual-wavelength, wide bandwidth feed

- Offset dual reflectors
  - Scaleable main reflector
  - High cross-pol isolation

- Splash plate
  - Shed water & snow
  - No exposed radome

- Simple Scanning

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DPR Antenna Feed

DPR Feed Cross Section

- Foam Sleeve
- Rexolite Rod
- To OMTs and radar
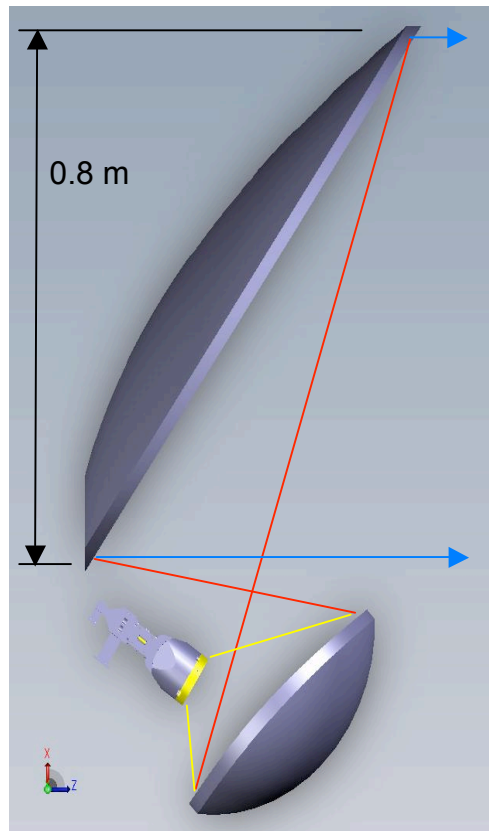- Corrugated Horn

Ku-band

Ka-band

- Dielectric rod carries Ka-band.
- Foam shaped Ka-band pattern.
- Corrugated horn carries Ku-band.
- Dielectric rod invisible to Ku-band.
- Independent control of Ku and Ka-band radiation patterns.
- ~2.56 ratio of Ku to Ka-band beamwidth.
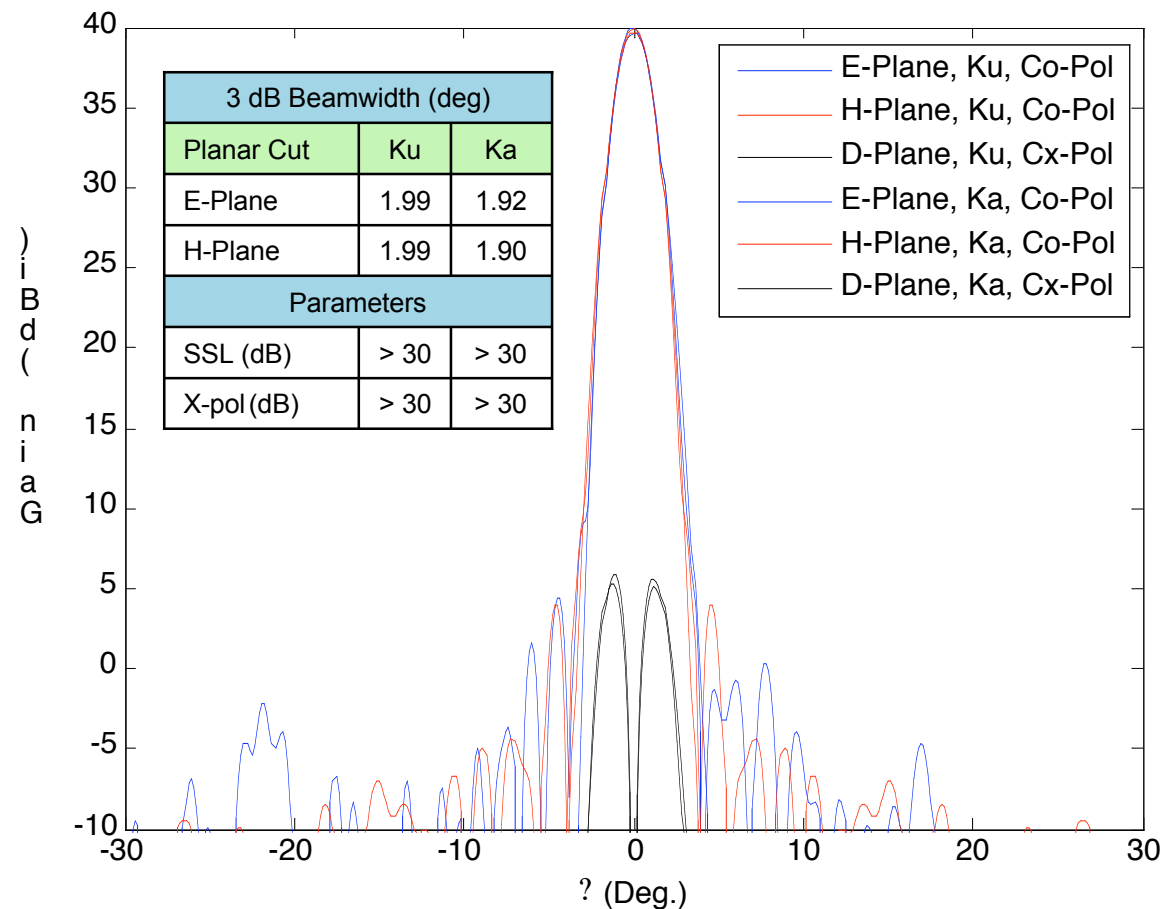- Supports V & H polarization.
- Cross-pol isolation > 30 dB.

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DPR Antenna Patterns

0.8 m

* Reflectors are modeled.

3 dB Beamwidth (deg)		
Planar Cut	Ku	Ka
E-Plane	1.99	1.92
H-Plane	1.99	1.90
Parameters		
SSL (dB)	> 30	> 30
X-pol (dB)	> 30	> 30

Legend:
- E-Plane, Ku, Co-Pol
- H-Plane, Ku, Co-Pol
- D-Plane, Ku, Cx-Pol
- E-Plane, Ka, Co-Pol
- H-Plane, Ka, Co-Pol
- D-Plane, Ka, Cx-Pol

Gain (dBi)

? (Deg.)

DPR Antenna Pattern – 1.6 m Diameter
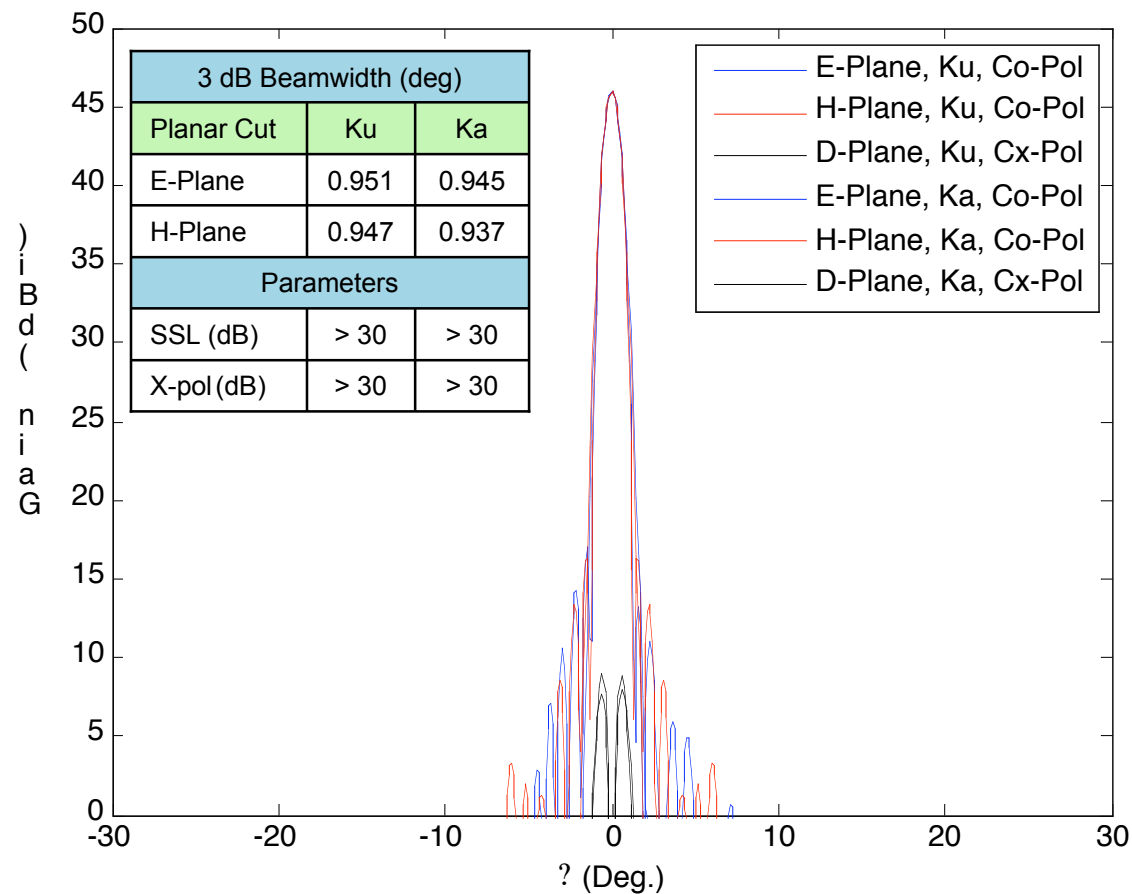
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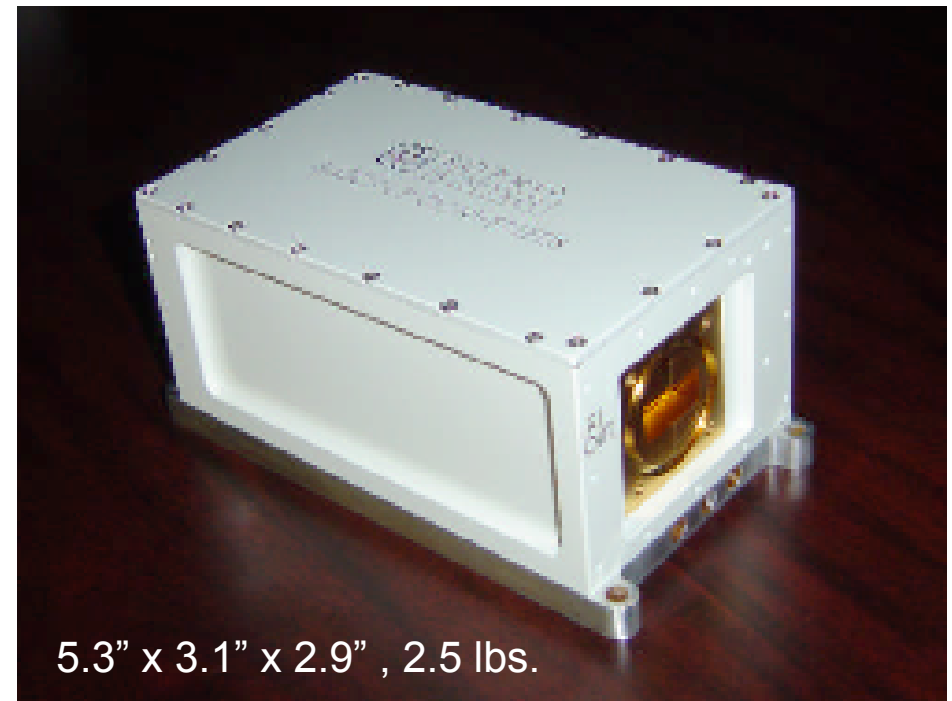
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DPR Transceiver
Design, Performance & Status

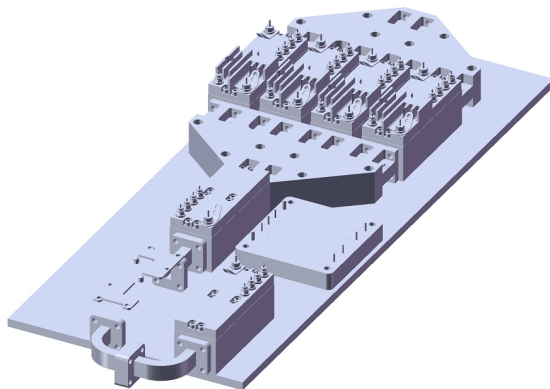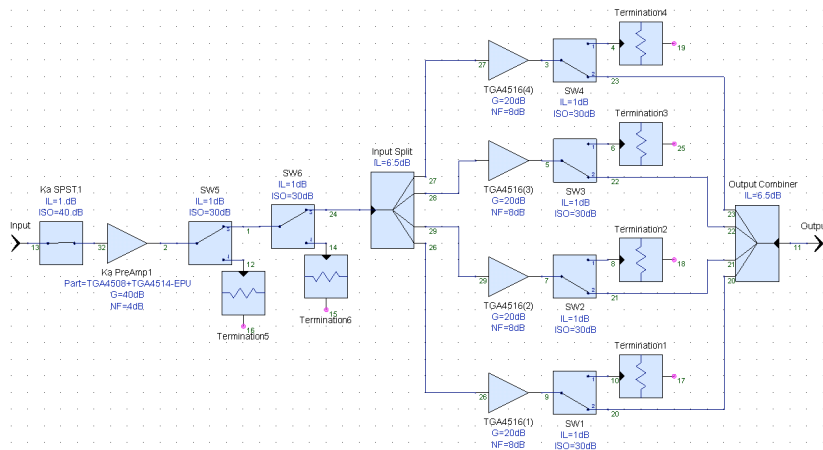# Solid-state Power Amplifiers

Ku-band Power Amplifier

- 13.0-14.0 GHz.
- 25 watts RF average power.
- Ultra efficiency
  (< 100W @ 28VDC).
- Compact & light weight.
- Operates up to 65 kft.
- COTS.

5.3" x 3.1" x 2.9" , 2.5 lbs.

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Solid-state Power Amplifiers
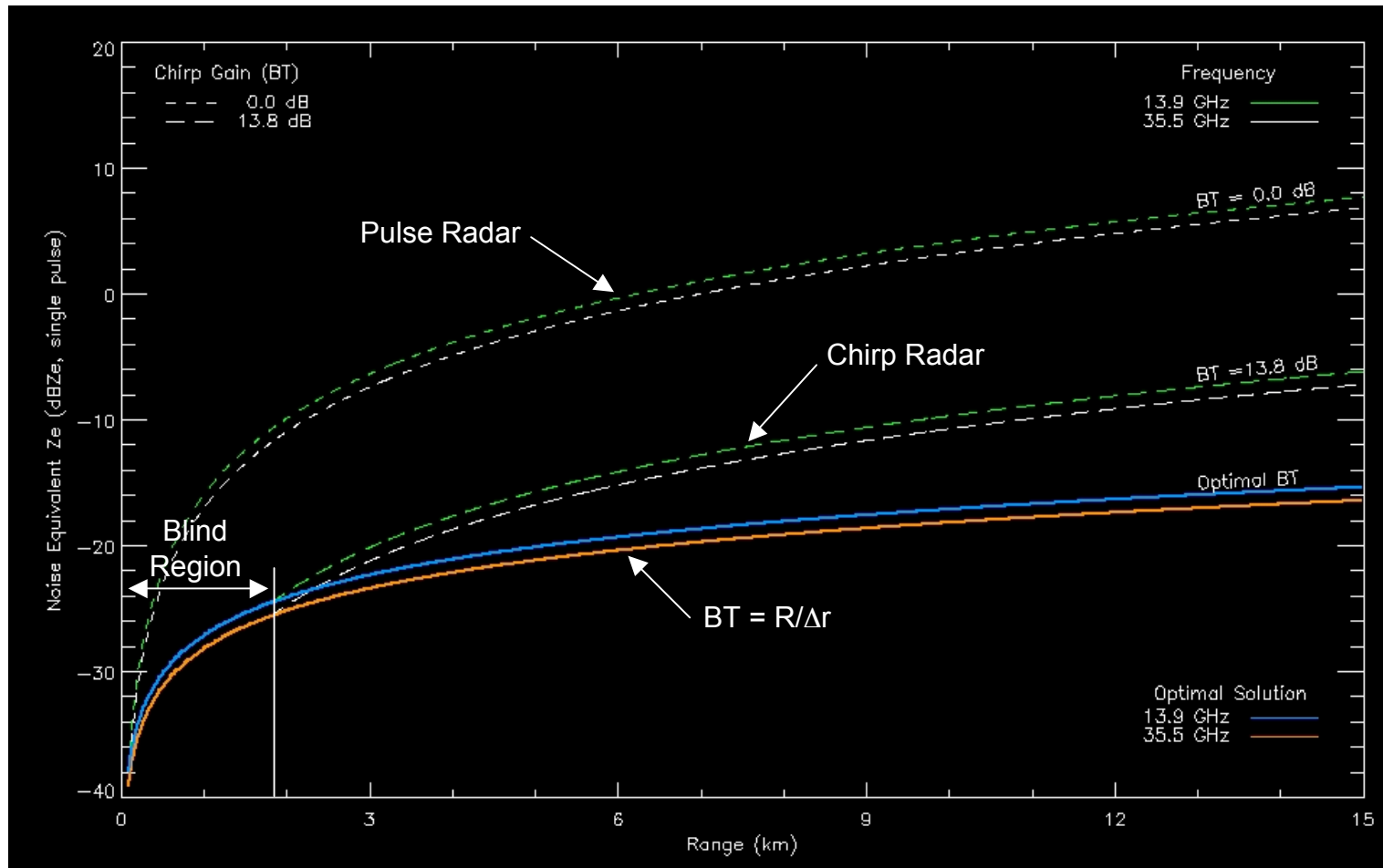

Ka-band Power Amplifier

- 33.67 – 35.61 GHz.
- 8 watts RF average power.
- Distributed Switching (10 nsec)
    > 120 dB on/off isolation.
- No Tx / Rx switch needed.
- Up to 100% duty cycle.
- Operates on 28 VDC.

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Conventional Approach

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DPR Transmit Waveform
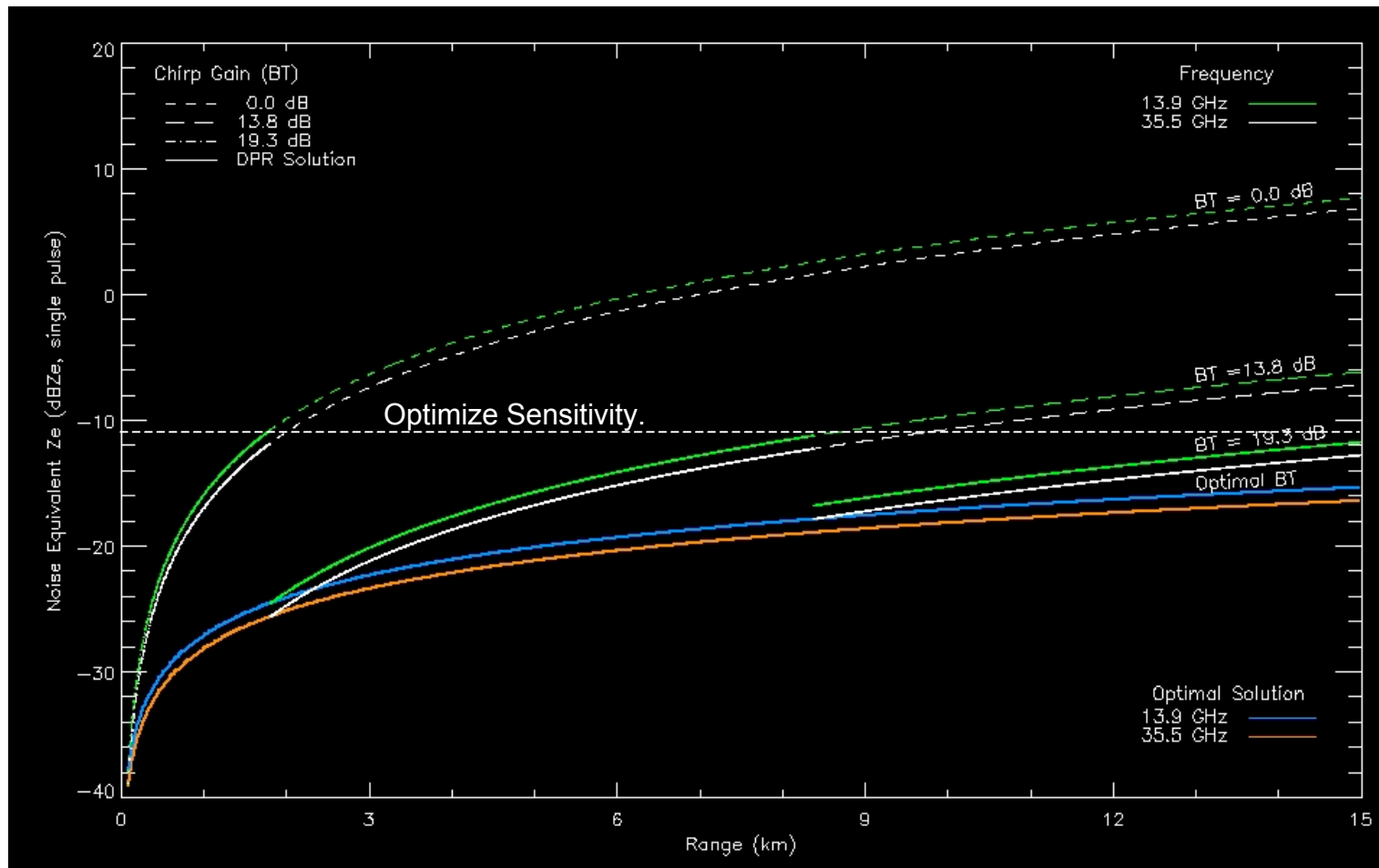
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DPR Transmit Waveform

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DPR IF Subsystem

IF Subsystem

• DDS-based Synthesizer Board:
- Generates multi-pulse transmit waveform.
- Provides amplitude control.
- Low cost.

• Provides RF receivers with LO's for
  IF down conversion to 120 MHz.

• High channel leakage rejection.

• High P1dB to ensure linearity.

• Printed circuit board implementation to
  reduce size.

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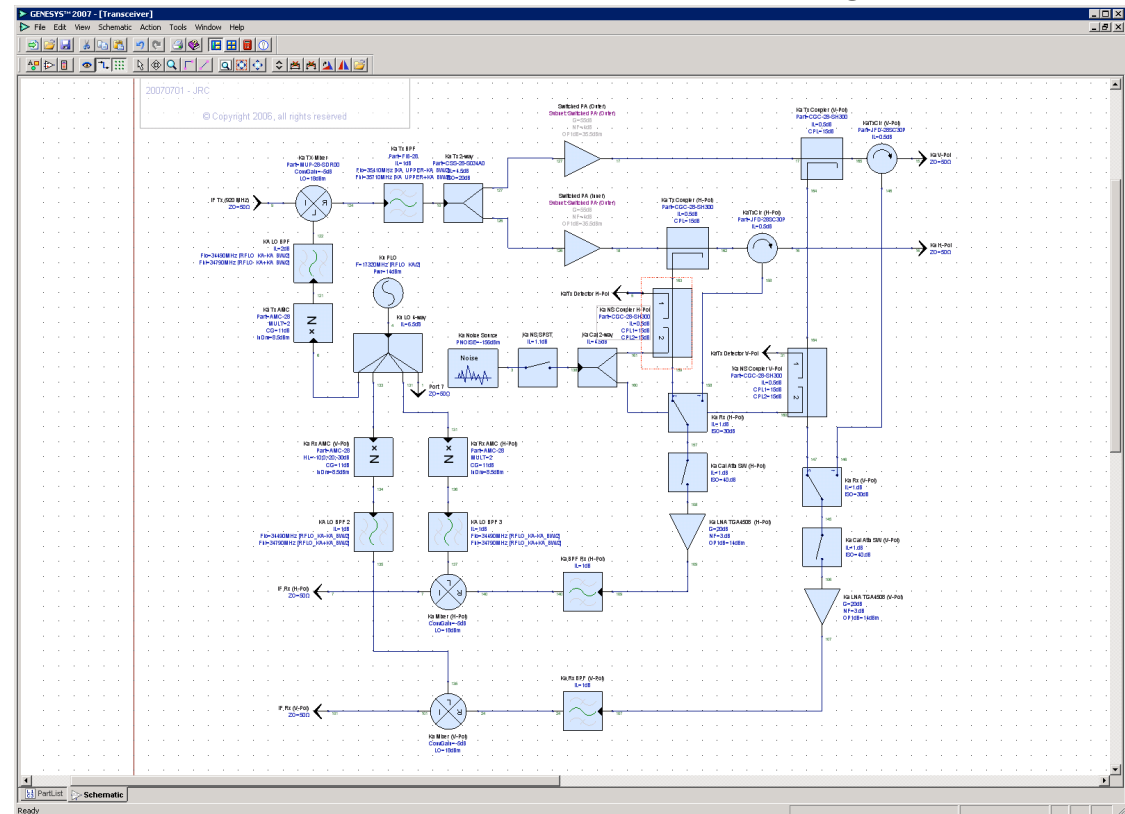SOLUTIONS

DPR Transceivers

Transmitter

- Independent V & H Tx Channels.
- 8 W Ka-band Ka-band Power Amp.
- 25 W Ku-band Power Amp.

Internal Calibration Loop

- > 35 dB Cal to leakage ratio.
- Direct transmit signal sampling.
- Dicke Noise Injection Circuit.
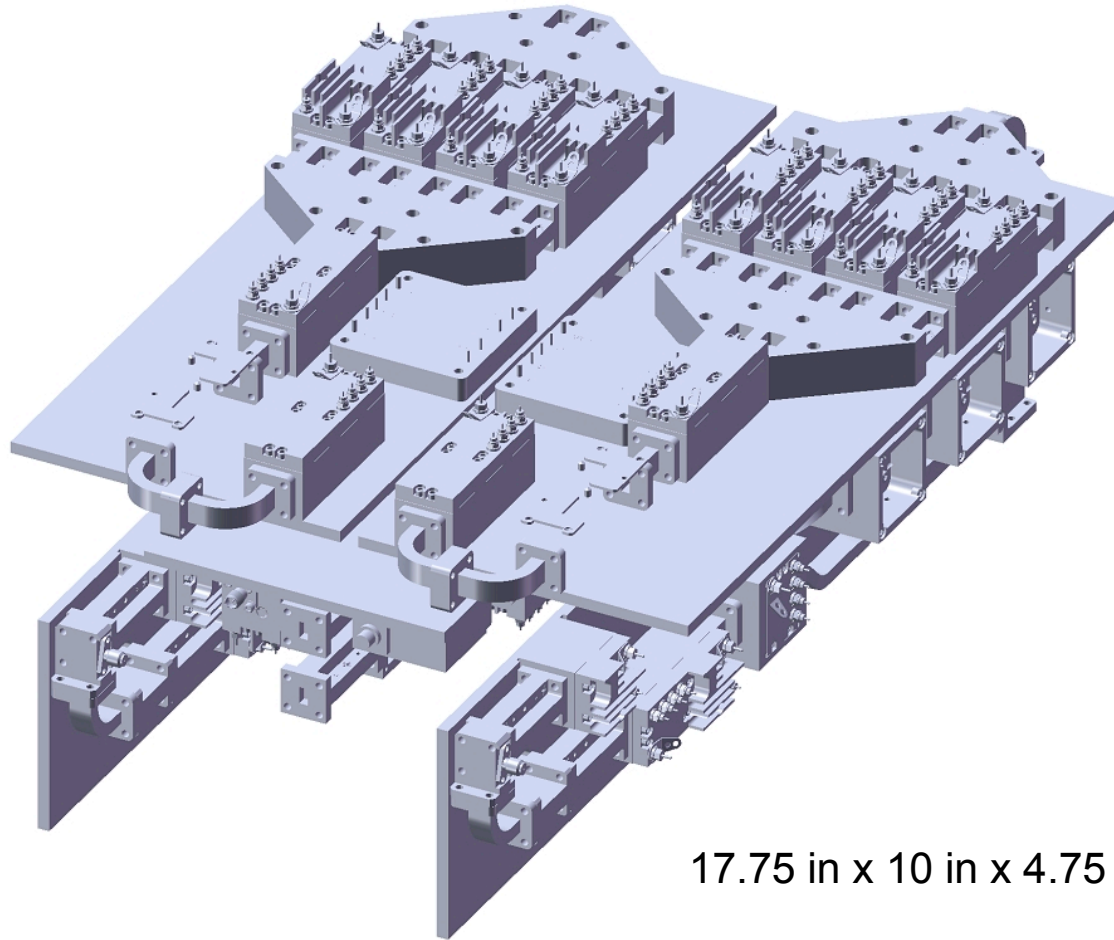
Receiver

- Ka-band Rx noise figure: 6 dB.
- Ku-band Rx noise figure: 4.2 dB.
- High compression point
       P1dB > +20 dBm.
- High rejection of Tx Leakage
    thru LO path.
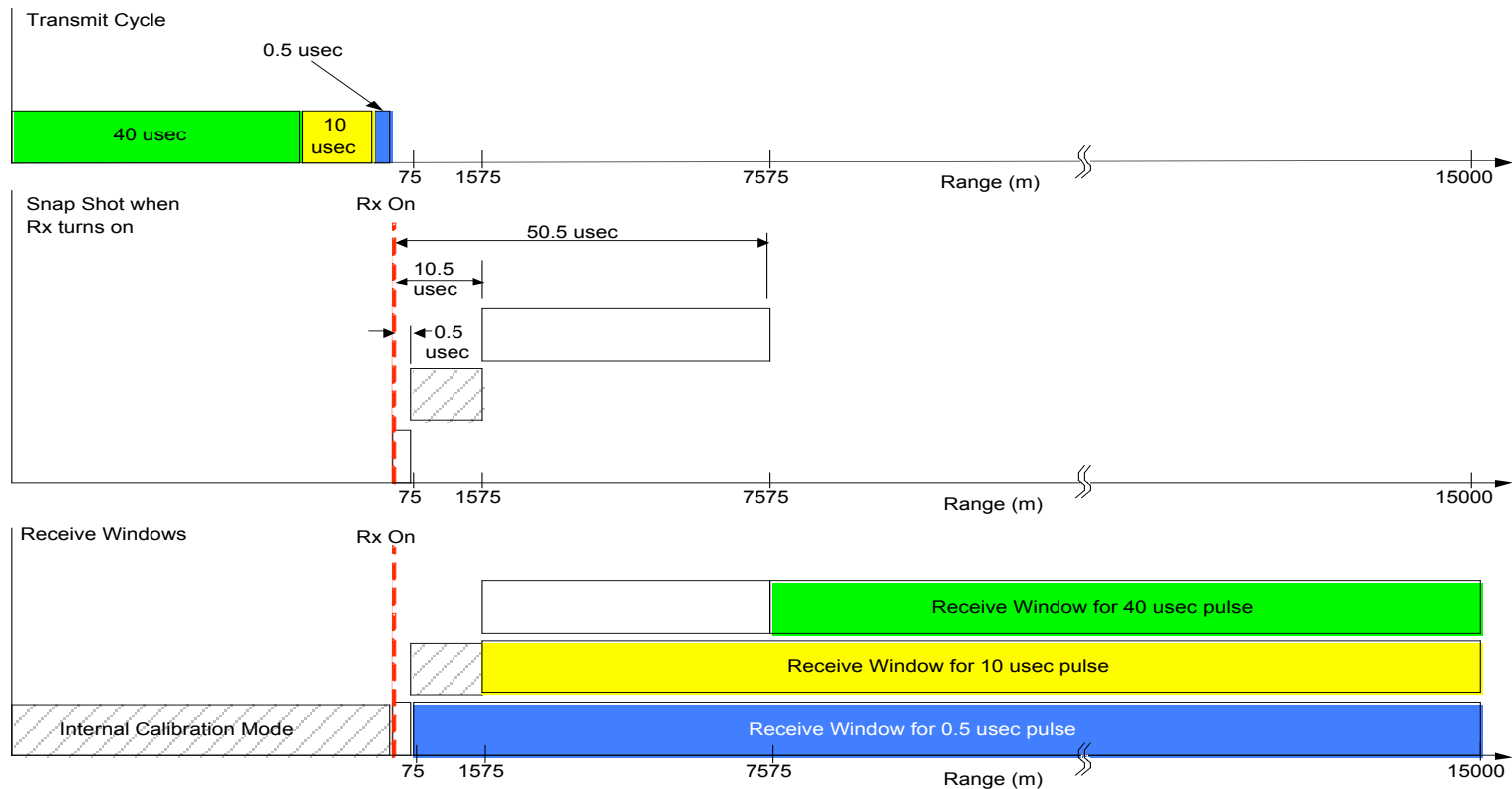
Ka-band Transceiver Block Diagram

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Ka-band Transceiver Layout

17.75 in x 10 in x 4.75 in

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DPR Transceiver Features

- Transceiver
  - Solid-state, compact and light weight design for remote & autonomous deployment.
  - High linearity to support pulse compression and dense packing of sub channels
  - Internal calibration provides 0.15 dB precision / stability.
  - Direct measurement of transmit waveform.
  - Active & passive measurements through same antenna.
  - HIWRAP compatibility (only swap filters).

- Dynamic, Multi-chirp Transmit Waveform.
  - Utilize > 80 % of power amplifier's average power.
  - Single aperture, pulse compression system with no blind region.
  - Optimize to scene / range under observation (1/R rolloff points).
  - Provides increased independent sampling rate.
  - Direct measurement of range sidelobe performance.

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DPR Performance (cont)

Parameter	Requirement	
RF Frequencies	Ku-band (13.91 GHz), Ka-band (35.56 GHz)	
Measurements	Co-pol & Cross-pol Backscatter and Doppler profiles Antenna Noise Temperature	
Measurement Products (per range gate)	Reflectivity Factors: Z_{VV}, Z_{HH}, Z_{VH}, Z_{HV} Phases: ϕ_v, ϕ_h, Differential reflectivity: Z_{DR}, Co-polar correlation coefficient: ρ_{hv}, Specific differential phase: K_{DP}, ϕ_{DP}, Linear depolarization ratio: LDR Radial Doppler Scene Brightness Temperature: T_{BV}, T_{BH} (full column)	
Polarization	Vertical and Horizontal, simultaneously	
Range Resolution	15 m – 150 m, 75 m (typical)	
Range Coverage	10 km (typical)	
3 dB Antenna Beamwidth	1.9 degrees	
Sensitivity ($dBZe_{min}$) (75 m range gate, 10 km range, 1 second)	Ku-band	Ka-band
	< -11 dBZ	< -12 dBZ

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DPR Performance (cont)

Parameter	Requirement	
Accuracy	Reflectivity < 1 dB Doppler < 1.5 m/s (SNR = 10)	
Precision	Reflectivity < 0.15 dB	
Relative Accuracy (between bands)	< 0.3 dB	
Dynamic Range	> 80 dB	
ΔT (100 MHz, 0.1 sec integration)	Ku-band	Ka-band
	< 0.2 K	< 0.4 K
PRF	1 – 20 KHz	
Range Sidelobe Suppression	> 50 dB first range sidelobe	
Crosspol Isolation	30 dB	
Matched Beam Performance	3 dB beamwidths matched to within less than 5%	
Scanning	Azimuth and elevation scanning	
Environment	All weather operations.	

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DPR / HIWRAP
Digital Receiver & Processor

HIWRAP / DPR Network-based Digital Receiver & Processor
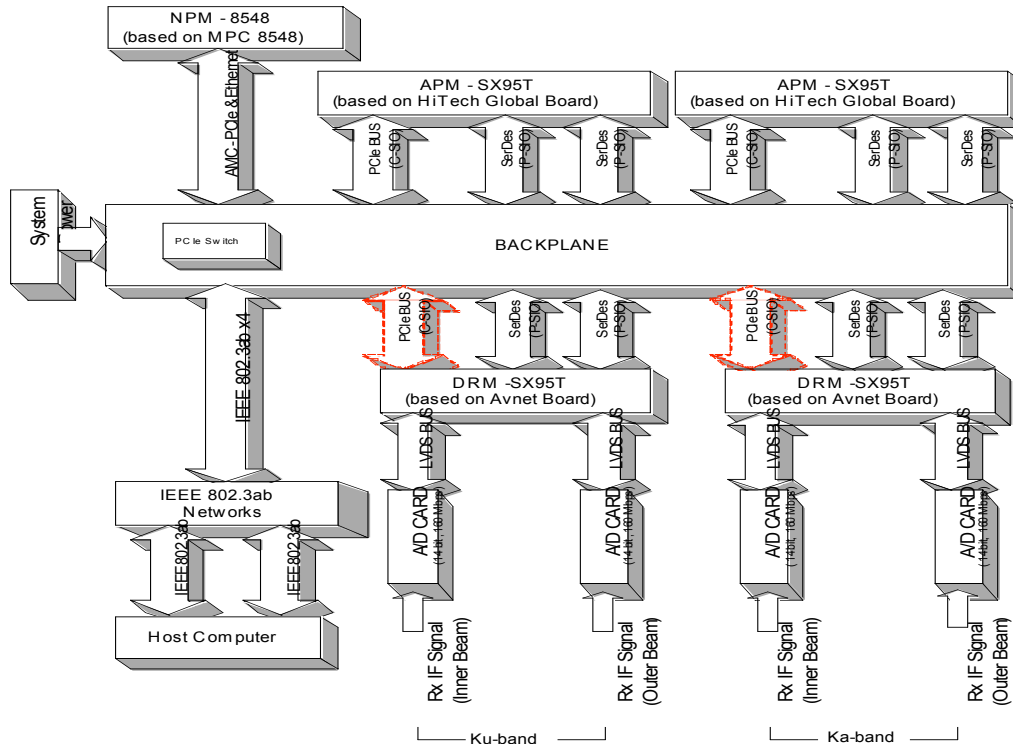
Primary Features:

- Modular (DRM, APM & NPM).

- FPGA Boards based on Xilinx SX95T.

- Reconfigurable and Redundant Design.

- Serial and parallel processing support.

- Up to four SRIO channels per card (3.2 Gb/s channel).

- 20 Gb/s 8 lane PCIe on backplane.

- Up to four Gigabit Ethernet connections to host network (IEEE 802.3ab).

- Hardware solution (software layer - NPM only).

- Open Source Solution – Embedded Linux OS.

- Expandable (support up to 10 APMs/DRMs).

- High altitude operation.

- Low power consumption.

- Minimal software layer.
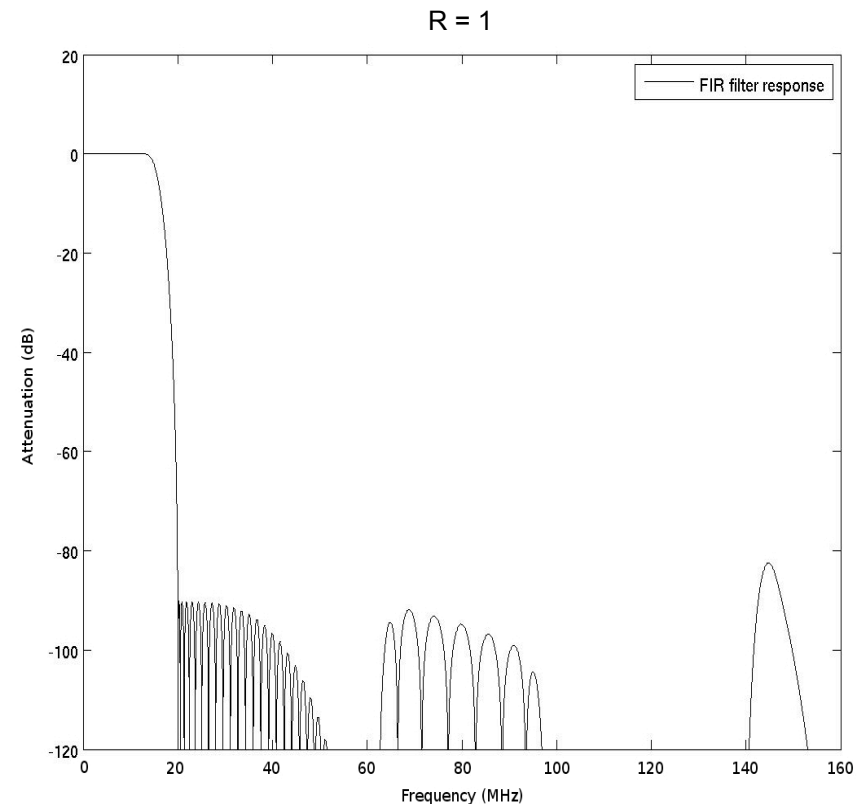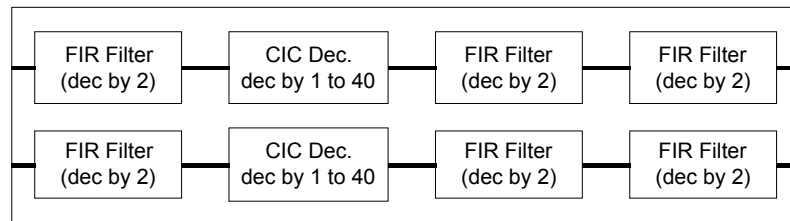
REMOTE SENSING SOLUTIONS

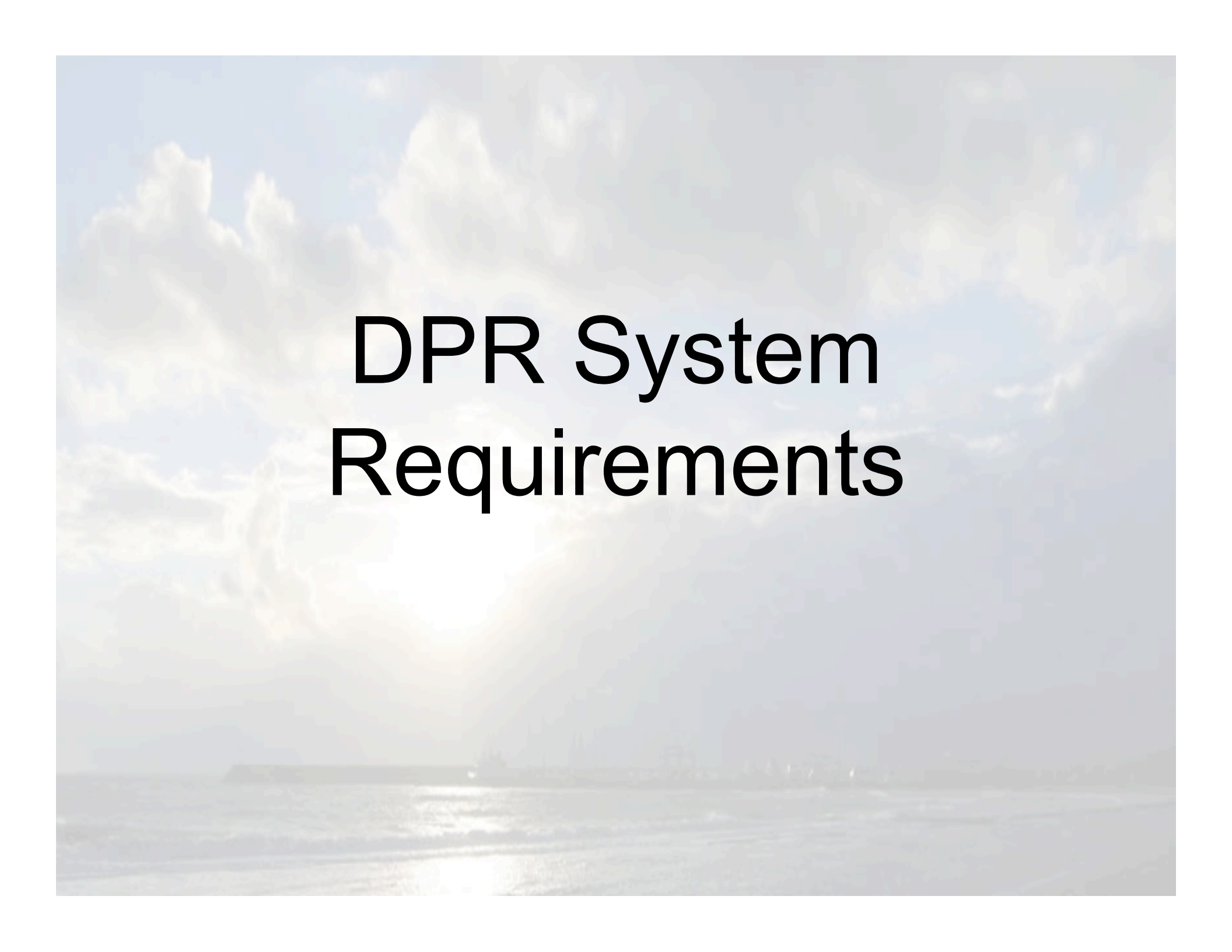# Multi-channel Complex Match Filter Digital Receiver Module (DRM)

- Two IF channels per board.
- Eight sub channels per IF channel.
    - 80 MHz Max Frequency.
    - 500 kHz Min Frequency.
    - 1 Hz resolution.
- Up to 20 MHz bandwidth per sub channel (500 KHz minimum).
- 40 MHz aggregated bandwidth per IF channel.
- Greater than 80 SNR.
- Operate up to 14 bit resolution.
- Match Filter supports up to 30 dB pulse compression gain.
- Supports up to 1000 range gates.
- Supports Frequency Diversity Doppler Processing in hardware (phase rotator following complex mixer).

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DRM Sub Channel Filter

Complex Video Filter

- Bandwidth 20 MHz / R where R = [1,40]

- Filter Shape = 1.5

- Sub channel Isolation > 90 dB prior to match filter.

- Reused for 2 sub channels through over clocking.

FIR Filter (dec by 2)	CIC Dec. dec by 1 to 40	FIR Filter (dec by 2)	FIR Filter (dec by 2)
FIR Filter (dec by 2)	CIC Dec. dec by 1 to 40	FIR Filter (dec by 2)	FIR Filter (dec by 2)

R = 1

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DPR System Requirements

DPR Weight & Power Budgets

Sub System	Weight (lbs)	Power (W)
Radar RF/IF	70	600
Antenna System (reflectors, splash plate and feed)	140	
Digital Receiver & Processor	20	150
Local Data System	25	100
Power Distribution	5	
Scanner & Frame	140	100
TOTAL	400	950

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Meeting Today's Requirements
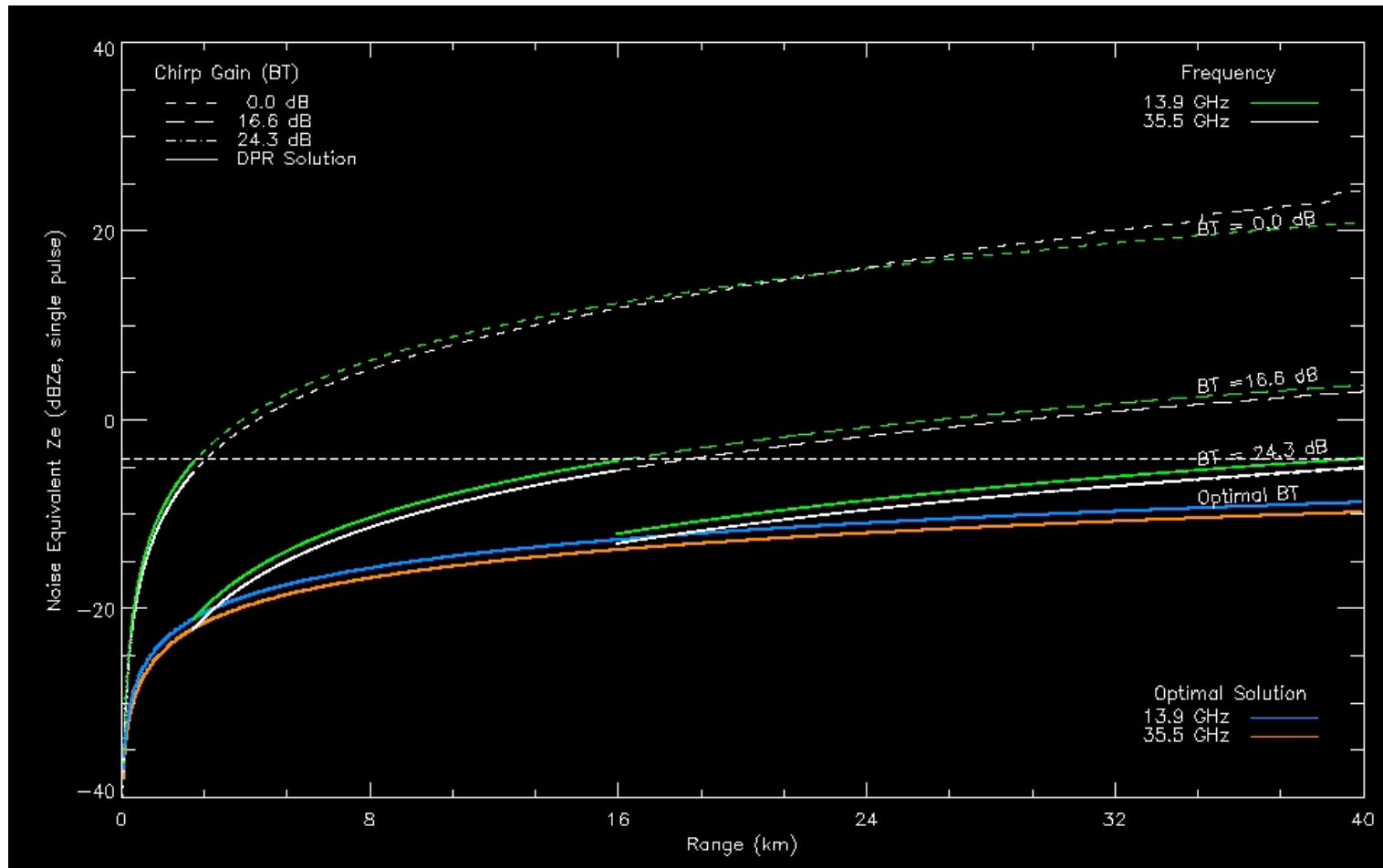
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DPR Schedule

Description	Completion
Ku-band Transceiver Layout	12 / 2007
IF Subsystem Layout	12 / 2007
Final Antenna Feed Fabrication	01 / 2008
Ku-band Transceiver Fabrication	02 / 2008
Ka-band Transceiver Fabrication	02 / 2008
IF Sub System Fabrication	02 / 2008
Full Antenna System Design	02 / 2008
Full System Design	03 / 2008
Delivery of Transceiver, Feed & Design Documents	04 / 2008
HIWRAP Digital Receiver & Processor*	Summer 2008

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Data Distribution Systems

- **Designed and Fabricating AAMPS**
  - Network based system.
  - Deployed on all NOAA Research Aircraft.
  - Web browser user interface.
  - Provides seats

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Early History

Remote Sensing Solutions, Inc. was founded in 2002 with the following goal:

> Provide leadership to remote sensing and research communities through technology transfer and innovative solutions that meet their needs.
> To transfer these advancements into viable commercial products for the public and private sectors.

RSS' Vision

- We saw an unmet position in the industry for a well experienced group of remote sensing and software engineers able to create end-to-end systems.

- We believe one of the keys to differentiation is the ability of the company to deliver complex radar designs with advanced data management interfaces.

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RSS to Date

- 7 SBIR/STTR Phase 1 Projects
- 2 SBIR Phase 2 Projects
- 2 Joint Hurricane Testbed Projects
- 1 HIWRAP Project
- Commercial & research institution projects

Most important: Established reputation with NASA & NOAA for delivering innovative remote sensing applications.

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NOAA AAMPS Project
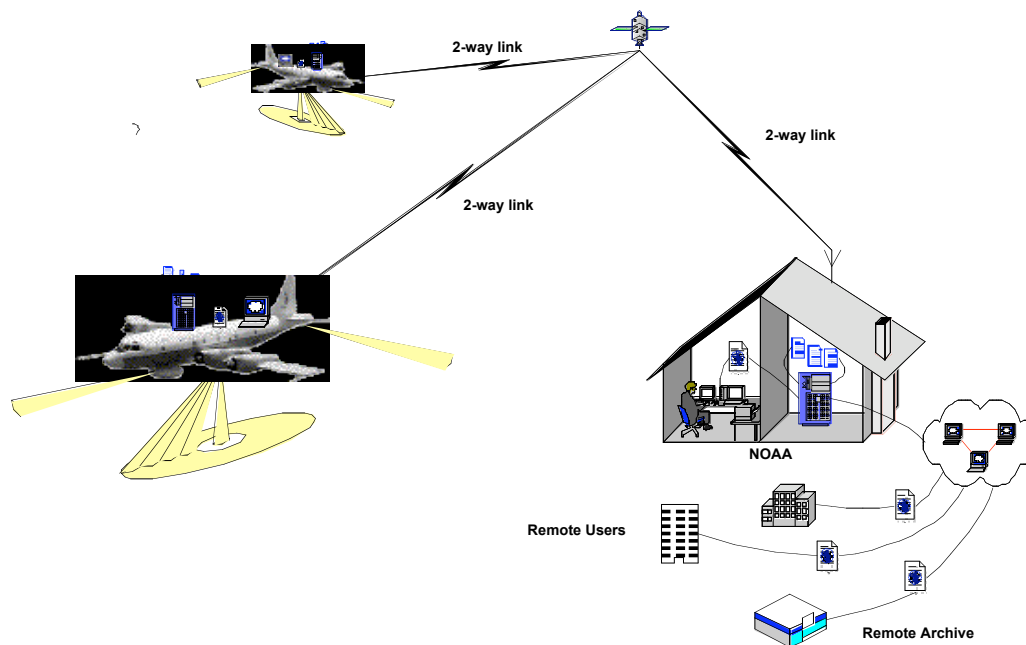
- Real-time Data Archive, Processing & Distribution System
- Web-browser user interface for control and data display
- Local and remote virtual seats.
- Open source and COTS based.
-

2-way link

2-way link

2-way link

NOAA

Remote Users

Remote Archive

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Storm Analyzer: Web Service

FEATURES

- Requires standard web browser.
- Real-time and Archive Views.
- Automatic detection and configuration of data streams.
- User Configurable
- Multiple Views
  - Time series
  - X-Y comparisons
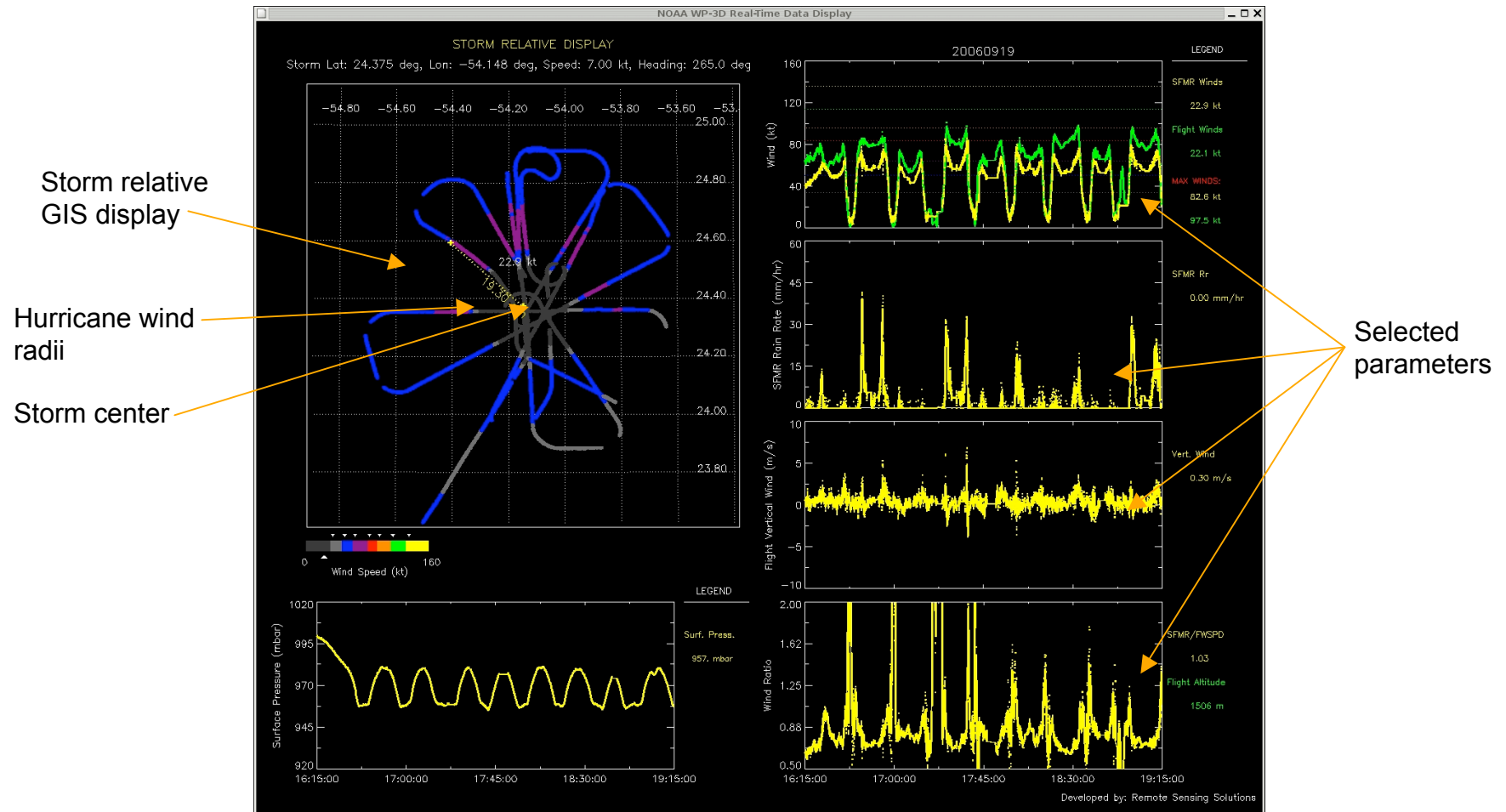 - 2-D imaging
  - Mapping
- JAVA based

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NHC Real-Time Display

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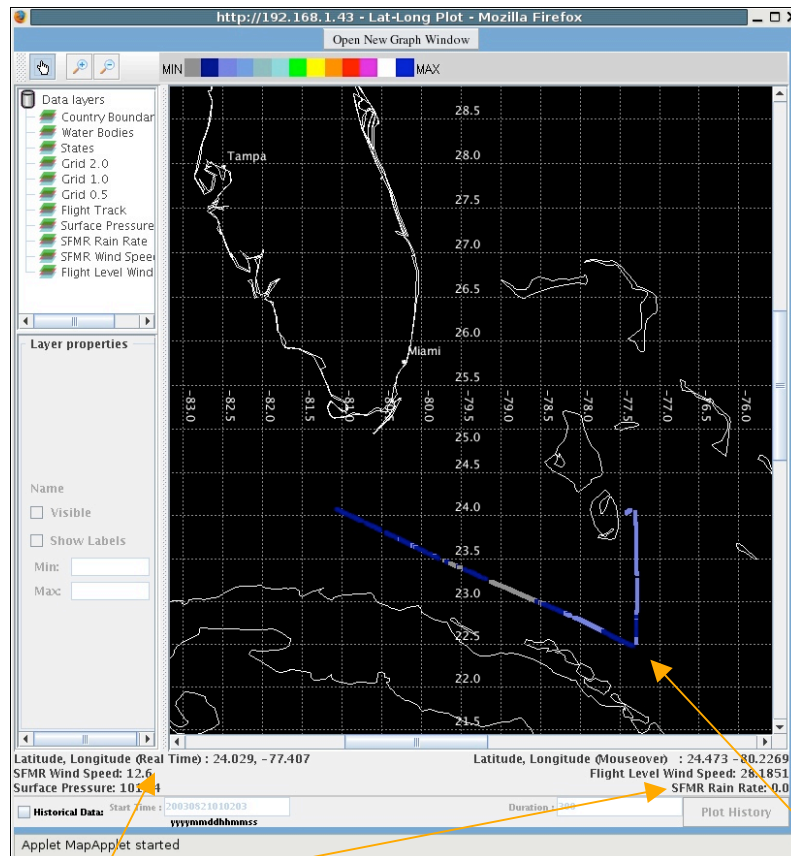
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Real-Time LF Ground Display

- Real-time processing and data distribution system providing 1Hz, AVAPS and Lower Fuselage data.

- Utilizes 64Kbaud satellite data link transmitting raw data via UDP to the ground for display and processing.

- Provides time series and GIS views of actual data (not images)

- Storm relative display for estimation of storm center and hurricane wind radii.

- Assists NHC and collocated FEMA personnel with forecasting and warning responsibilities.

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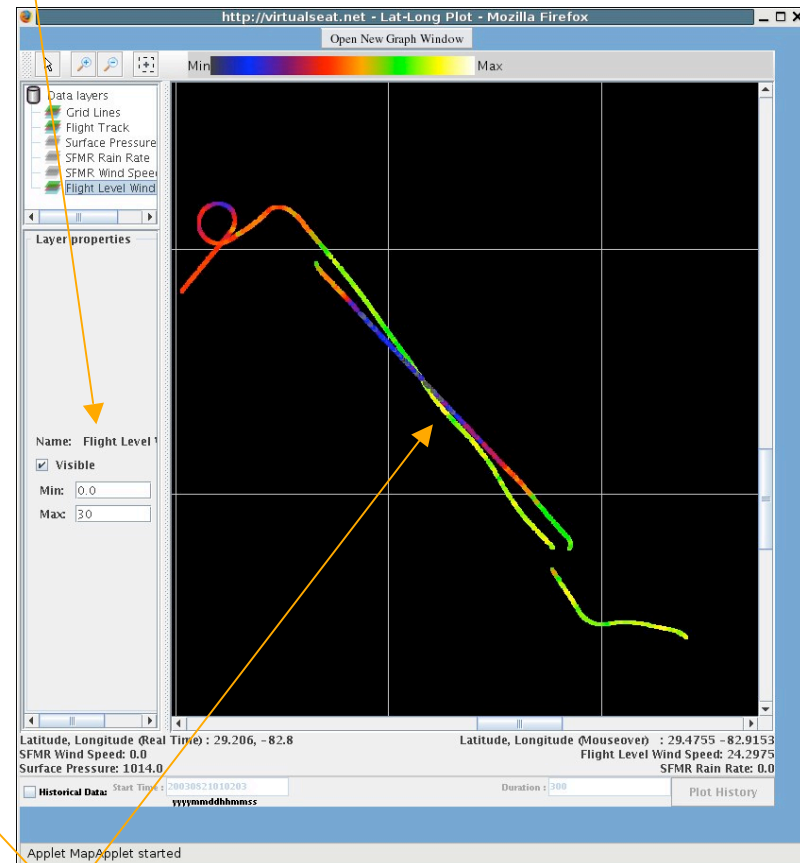
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Storm Analyzer Data System

- Initially designed for NOAA to acquire WP-3D serial 1 Hertz data stream.
- Web-based data acquisition, analysis and distribution system:
  - Receives data streams via serial and Ethernet ports.
  - Auto detects parameters in each data stream and parses the data.
  - Time tags and stores the parsed data to a hard drive (RAID) in netCDF format.
  - Allows users to select experiment and flight of interest.
  - Allows users dynamic selection of data parameters for real-time display.
  - Provides customizable time series plots and GIS overlays.
  - Allows visualization of archived data.
  - Forwards aircraft data streams to a ground station via a satellite data link in real-time.

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Storm Analyzer GIS Display

Chosen data parameter

Aircraft position and real-time data parameter values

Data parameter value overlay on aircraft flight track

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